UNIT - 5

CHEMISTRY FOR CLASS IX

CHEMICAL BONDING

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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PREFACE

The present series of twelve chemistry units has been developed for try-out of the Individually Guided System of Instruction (IGSI) in class IX The description of IGSI and first two units of this series of units are available under a separate cover. This new system of instruction and the units have been developed along the lines of the National Policy on Education (NPE-86) and involve the participation of pupils in the process of learning. The units are suited for self-study with occasional help from a tutor. In the present context, these units will serve an examplar self-study material for secondary stage chemistry. In developing this unit, I was assisted by some of the chemistry teachers.

This unit contains an introduction for motivation, arousing interest, and to link the present unit with preceding and next units. The objectives given in this unit are the expected learning outcomes, so that the pupil will know the ultimate goals he has to achieve. The suggested reading material provided in the unit guides the pupil to achieve pre-stated objectives. A number of intext and post-text questions, activities, and problems have been included to provide enough practice and chance for self evaluation.

The suggestions for the improvement of this unit will be welcomed.

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March, 1988

I Introduction

In previous units we have studied about matter. It is composed of elements as well as compounds. For example, common salt is composed of sodium chloride, (Na Cl), which is a compound of sodium and chlorine. The paper on which we write, the wheat floor and rice that we use for cooking food, are all composed of complex compounds consisting carbon, hydrogen and oxygen. These compounds are made up of molecules. The molecules consist of atoms held together by certain attractive forces.

We have also studied that a molecule is formed by a combination of two or more atoms. Have you ever thought as to why and how atoms combine to form molecules. In this unit, we shall discuss about the formation of molecules from atoms.

II Objectives

After completing this unit, you should be able to

1. Identify the forces that work between two combining atoms.
2. Illustrate the principles underlying the formation of a molecule from two atoms.
3. Explain of the combination of atoms resulting in the formation of electrovalent and covalent bonds.
4. Distinguish between electrovalent and covalent compounds on the basis of their properties.
5. Illustrate the formation of single, double and triple bonds.
6. Give reasons for the ionic character of covalent bond.

III Suggested Reading Material

5.1. Forces working between two combining atoms

On the basis of our knowledge of structure of atom studied in the previous unit, let us consider the forces that work between two hydrogen atoms.

As the two hydrogen atoms are brought closer, three types of forces operate between them ;

(a) attraction due to the nucleus of one atom and electrons of another and vice-versa.

(b) repulsion due to the electrons of the two atoms and

(c) repulsion due to the nuclei of two atoms

At a certain optimum distance between the nuclei of two atoms, the attractive forces (category-a) are more then the repulsive forces (category - b & c). Therefore the two atoms are held together and a molecule of hydrogen is formed. The force of attraction which holds the two atoms together in a molecule is known as *chemical bond*. The distance between the nuclei of two atoms, held together by a chemical bond, is known as *bond length*. (Fig. 5.1)

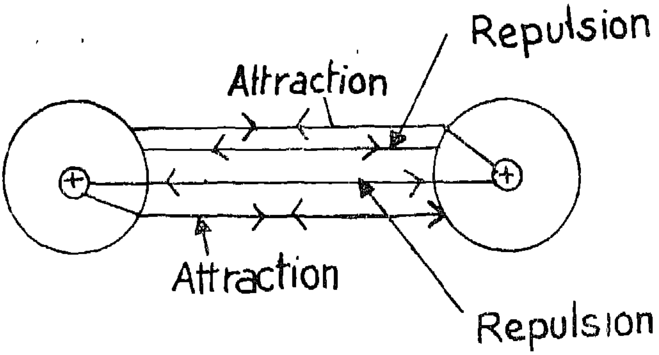


Fig. 5.1 Attractive and repulsive forces in the formation of a chemical bond.

5 2. Energy and chemical bond

The formation of bond between two atoms can also be explained on the basis of energy changes. We know that every atom is associated with certain amount of energy. Mutual attraction of the two atoms, as described above brings about a decrease in their potential energy The resulting molecule will thus have less energy than the sum of the energies of two combining atoms We know that everything in this universe tries to attain a minimum energy level For example, when a ball is thrown up in the air, it will definitely come to the ground where its potential energy becomes zero. Due to the same reason, the atoms combine with each other to form molecules and become stable. Thus the formation of a molecule from two atoms or the formation of a chemical bond between two atoms invlolves the release of energy, If we are to break a chemical bond, the energy must be supplied.

Questions

1 Explain the following terms :

(a) Chemical bond and

(b) bond length

2. In the formation of a molecule AB, the decrease in energy is much more than in the formation of another molecule D. Which is a more stable molecule and why ?

3. What happens to the energy of a system in the formation of a chemical bond ?

5.3 Chemical bonding and electronic configuration

The noble gases exhibit little chemical activity and their combining capacity is regarded as zero. Their atoms do not combine with atoms of metals, or non-metals. Also the outermost shells of atoms of all these elements (except helium) contain eight electrons. A set of eight electrons in a shell is called an octet.

Table - 5.1

Noble gas	Electrons in shells (from inside out)
Helium	2
Neon	2,8
Argon	2,8,8
Krepton	2,8,18,8
Xenon	2,8,18,18,8
Radon	2,8,18,32,18,8

From this it was inferred that noble gases are stable because of the presence of an octet of electrons in the outermost shells of their atoms. Hence they do not ordinarily combine with other elements. The atoms of all other elements show a tendency to get an octet of electrons in their outermost shells by a gain or loss or sharing of electrons. In this process, these atoms acquire the electronic configuration of the nearest noble gas. For example, carbon, electronic configuration (2,4), has four electrons in the outermost shell. It will acquire the electronic configuration of the noble gas, neon, (2,8) in combined state. Only the electrons in the outermost shells take part in these electronic adjustments. The outermost shell electrons in an atom are called its valency electrons. Thus the atoms can attain an octet of electrons in their valence shells by a gain, loss or sharing of an adequate number of electrons

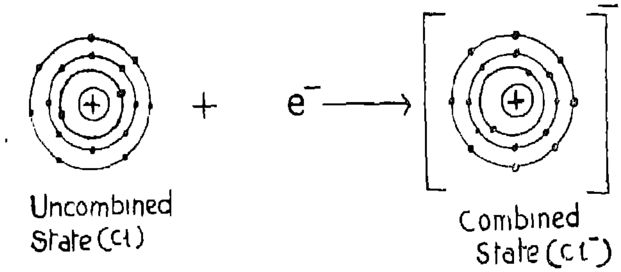


Fig. 5.2. Formation of anion

Chlorine atom has seven electrons in its outermost shell. It completes its octet by a gain of one electron. Sodium **atom**, electronic configuration (2,8,1), loses one electron to acquire the configuration of noble gas, neon.

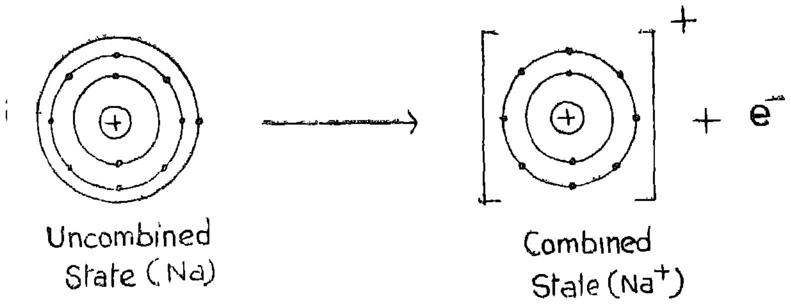


Fig. 5.3 Formation of cation

Questions

1. Why are noble gases unreactive ?
2. Which inert gas has less than eight electrons in its outermost shell ?
3. What are the different ways in which an atom can achieve the inert gas confiuration ?

5.4. Electrovalent or ionic bond

Let us consider the chemical reaction between sodium and chlorine atoms to form sodium chloride. Let us write down the electronic configurations of sodium and chlorine atoms.

Atomic number of sodium = 11,

no. of electrons = no. of protons = 11

Atomic number of chlorine = 17

No. of electrons = no. of protons = 17

Now check your answer from the electronic configurations of chlorine and sodium as shown in figures 5.2 and 5.3 respectively.

Atoms of both these elements do not contain 8 electrons in their outermost shells. Thus each one of them has a tendency to attain a stable configuration of the nearest noble gas. In case of sodium, the next noble gas is neon (at no 10) and in case of chlorine it is argon (at. no. 18). Let us see how the stable noble gas configurations are acquired by sodium and chlorine atoms. In order to acquire the electronic configuration of neon, sodium atom loses one electron from its M shell. The L shell next to it would become the outermost shell and it has eight electrons. Thus, after losing one electron, sodium atom attains the stable electronic configuration of the noble gas neon i e, 2,8 Now sodium has 10 electrons and 11 protons The sodium atom now acquires a unit positive charge and becomes cation (Na^+) (Fig 5 3). Similarly when an electron is added to the M shell of chlorine atom, it completes its octet and thus attains the stable configuration of the nearest noble gas, argon (2,8,8) Due to the gain of one electron,chlorine acquires a negative charge and becomes chlorine anion (Cl^-) (Fig 5 2).

The number of electrons gained, lost or shared in bond formation is known as the valency. Both sodium and chlorine have a valency of one (The valency of an atom is determined by the number of hydrogen atoms with which an atom of the element can combine. For example in HCl, one chlorine atom combines with one hydrogen atom. So the valency of chlorine is one. In $MgCl_2$, the valency of magensium is two as one magnesium atom combines with two chlorine atoms.)

Due to their opposite charges, the sodium ion (Na^+) and chlorine ion (cl^-) attract each other due to the electrostatic force of attraction Thus a bond is formed between sodium and chlorine forming sodium chloride (NaCl) molecule. The bond formed between two oppositely charged ions is known as electrovalent bond. The compounds having electrovalent bonds are known as electrovalent compound.

Let us consider the formation of electrovalent bond in a few compounds

(i) Aluminium reacts with chlorine to form aluminium chloride, $Al Cl_3$.

The electronic configuration of aluminium atom (at. no. 13) is as follows :

K	L	M
2	8	3

Aluminium atom loses three electrons to attain the stable electronic configuration of the nearest noble gas, neon (2,8) and forms an aluminium ion. Al^{3+}. We know that an atom of chlorine requires only one electron to attain the configuration of nearest noble gas, argon. 2, 8, 8. So 3 electrons from one aluminium atom are transferred to three chlorine atoms. Three chloride ions are thus formed Now three electrovalent bonds are formed between one aluminium and three chlorine atoms and a molecule of aluminium chloride, $Al\,Cl_3$, is formed

Activity Explain the electrovalent bond formation in $Mg\,Cl_2$ & Na_2S.

5.5 Characteristics of electrovalent compounds

(i) They have high melting and boiling points To melt or boil a compound mean to convert it into liquified or gaseous state respectively Electrovalent molecules in the solid state are closely bound to each other by electrostatic forces of attraction between them When such a solid compound is melted,the oppositively charged ions are taken apart against their mutual attraction. This requires high energy. Hence lot of energy in the form of heat is required to melt an electrovalent compound Thus they have high melting points Similarly in gaseus state the ions are kept still far apart from each other which will require still more energy Thus they will have high boiling points also

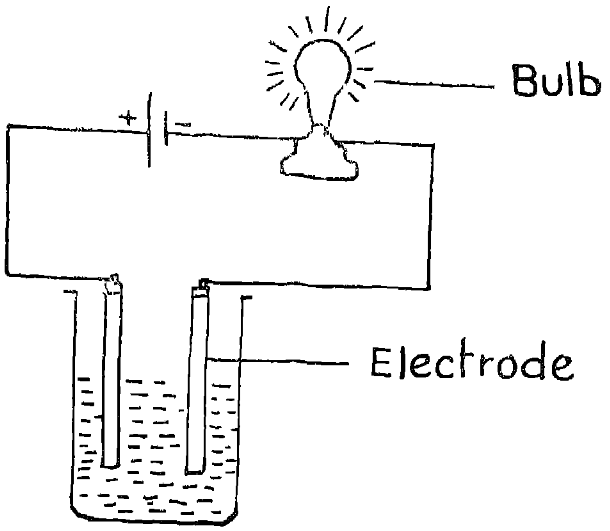
(ii) Electrovalent compounds dissolve in water producing oppositely charged ions. For example $Mg\,Cl_2$, when dissolved in water forms Mg^{2+} and 2 Cl^- ions. These compounds are insoluble in organic solvents.

$$Mg\,Cl_2 \longrightarrow Mg^{2+} + 2\,Cl^-$$

(iii) Electrovalent compounds conduct electricity in aqueous solutions or in molten state.

Activity

Take three 100 C.C. beakers containing sodium chloride, potassium bromide and magnesium chloride respectively Pour a few C.C of water in each beaker and stirr the solutions. Now arrange the apparatus as shown in figure 5.5. When an electric current is passed through an aqueous solution of sodium chloride, the bulb starts glowing. Similar observations are made with the solutions of potassium bromide and magnesium chloride.



Fig, 5.5 Conduction of electricity through aqueous solution of an electrovalent compound.

Questions

1. What are the different ways in which atoms complete their octet requirements ?
2. Three elements A, B, and C have the following electronic configurations :

	K	L	M
A	2,	6,	
B	2,		
C	2,	8,	8

Find out the inert gas/gases out of A, B, and C.

3. Fill in the blanks :

I. $Mg \longrightarrow Mg^{2+} +$

Protons $= 12$ Protons in Mg^{2+} =.........

Electrons= 12 Electrons in Mg^{2+} = ...

II. $O + \ldots\ldots \rightarrow O^{2-}$

Protons $= 8$ Protons in O^{2-} = ...

Electrons $= 8$ Electrons in O^{2-} = ...

4. Explain why sodium chloride has high melting point ?

5.6 Covalent bond

In many cases the atoms can not complete the desired octet in their valency shells by transfer of electrons. It is because both the combining atoms have a deficit of electrons in their outermost shells compared to the nearest noble gases. For example, in the formation of Cl_2 from two chlorine atoms, each chlorine atom has seven electrons in its outermost shell. In order to attain the configuration of argon (2, 8, 8) each Cl atom needs one electron. In such cases, atoms attain a stable configuration by sharing of electrons between the combining atoms. Each atom provides an equal number of electrons for the resulting bond formation.

Let us consider the formation of chlorine molecule. A chlorine molecule has two atoms of chlorine. The electronic configuration of chlorine atom, as already discussed, is as follows :

K	L	M
2	8	7

Thus a chlorine atom is short of one electron compared to argon atom (2, 8, 8). It can not complete its octet by gaining an electron from the other chlorine atom as the atom losing the electron will then have two electrons short of the required octet. The only way both Cl atoms can have 8 electrons in their outermost shells is by sharing of electrons. Each of the atoms provide one electron in sharing as shown in figure 5.4. Thus the bond which is formed by sharing of electrons between two atoms is known as *covalent bond*.

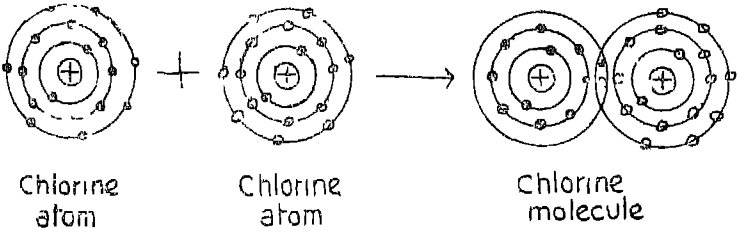


Fig 5 4 Formation of chlorine molecule from two chlorine atoms

Let us consider the fromation of oxygen molecule Two atoms of oxygen combine to form a molecule of oxygen by mutual sharing of four electrons. The electronic configuration of oxygen atom is 2, 6, 8. In the formation of oxygen molecule, O_2, each oxygen atom shares two electrons of the other atom. The sharing of two pairs of electrons between two oxygen atoms amounts to formation of two covalent bonds or a double bond between them Formation of oxygen molecule may be represented as shown in figure 5 6. In case of nitrogen, two atoms of nitrogen combine to form a molecule of nitrogen (N_2) by sharing of three pairs of electrons.

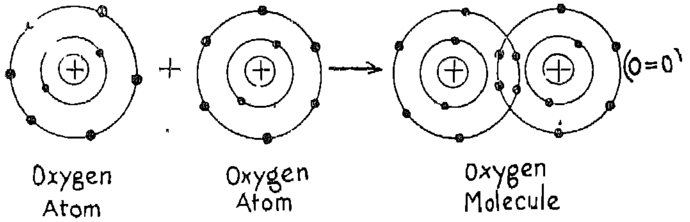


Fig. 5.6. Formation of a double bond in oxygen molecule.

Thus, if two pairs of electrons are shared between two atoms, a double bond is formed between them and if three pairs of electrons are shared between two atoms, a triple bond is formed.

Let us consider a few more examples of covalent bond formation:

(i) Methane (CH_4) :

In this case, foure atoms of hydrogen share one electron pair each, with an atom of carbon to form four single covalent bonds. (Fig.5.7)

(ii) Carbon tetrachloride (CCl_4) :

Four chlorine atoms combine with one carbon atom to form carbon tetrachloride.

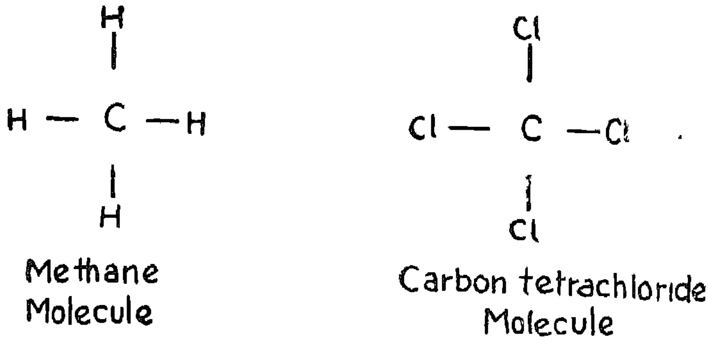


Fig. 5.7 Formation of CH_4 & CCl_4 molecule.

Characteristics of covalent compounds

1. Covalent compounds do not contain any ions. Therefore they are poor conductors of electricity.
2. Covalent compounds generally have low melting and boiling points.
3. Covalent compounds are generally insoluble in water and dissolve readily in organic solvents like ether, benzene, alcohol, etc.

Questions

1. What type of elements form Covalent Compounds ? Describe the bonding in methane.
2. What is the name of a chemical bond formed by the sharing of electrons between two atoms ?

When a covalent bond is formed between two like atoms such as between two chlorine atoms, the shared electron pair is equally attracted by two nuclei. As a result of this, shared-pair of electrons is symmetrically located between the two atoms, However, if we consider a covalent bond between two unlike atoms as in H-Cl (hydrogen chloride), the situation in respect of the shared pair of electrons is very different. The shared electron pair is found to be slightly towards the chlorine atom. This is because the attraction exerted on the shared electron pair by the chlorine nucleus is more than that exerted by the hydrogen nucleus. This causes an imbalance in the molecule. Thus chlorine atom acquires a slight negative charge and the hydrogen, a slight positive charge. $\overset{\delta+}{H}\rightarrow\!\!-\overset{\delta-}{Cl}$. $\delta+$ and $\delta-$ represent very-very small positive and negative charges respectively. Such molecules are said to be *Polar molecules*. The respective commounds are called *Polar Compounds*. Water is also an example of a polar compound.

Questions

1. What type of chemical bond is present in the molecule of a solid compound which has high melting point and is non-conducting when solid ? It becomes a good conductor when fused.
2. How do reacting atoms acquire the noble gas configuration in the formation of a covalent compound ?
3. An element 'A' has 4 electrons in the outermost shell of its atom and, combines with another element 'B' having 7 electrons in the outermost shell of its atom. The compound formed does not conduct electricity. What is the nature of the chemical bond in the compound ?

IV Home Assignments

1. The elements A, B, C and D have the following electronic configurations :

	K	L	M	N
A	2,	8,	6	
B	2,	8,	8	
C	2,	8,	8,	1
D	2,	7		

(I) What type of bond, element C will form with element D ?

(II) Which element is a noble gas ?

(III) What will be the formula of the compound formed by A and C ?

2. An element 'A' has four valency electrons in its atom whereas element B has only one valency electrons in its atom The compound formed by A and B does not conduct electricity. What is the nature of chemical bond in the compound formed ?

3. An element M burns in oxygen to form an electrovalent compound MO. What compounds will be formed if this element is made to combine with chlorine and sulphur respectively ?

4. Fill a burette with water. Rub a glass or ebonite rod with silk and fur respectively. Allow water to come out of the burette nozzle in the form of a stream. Take the rubbed glass or ebonite rod near the stream of water,

   (i) What happens to the stream of water ?

   (ii) Can you suggest an explanation for this behaviour ?

5. Describe with the help of diagrams the bonding in the following molecules :

   (I) N_2 (II) H_2O

   (III) $CaCl_2$ (IV) SO_2

6. What do you understand by the ionic character of a covalent bond ? Give one example.

V Self Assessment

1. Inspite of the forces of attraction and repulsion between the nuclei and electrons of two atoms, they combine to form a molecule. Discuss the balancing of these two types of forces taking hydrogen molecule as an example.

2. What are the different ways in which atoms complete their octet to attain noble gas configuration ?

3. Explain the formation of Cl_2, O_2 and N_2 with special reference to single, double and triple bonds.

4. Compare the property of electrovalent and covalent compounds concerning their conductivity.

5. How can you explain the polar character shown by covalent compounds ? Give at least two examples of such compounds ?

6. A compound having chlorine as one of its constituents does not dissolve in water and does not give white precipitate with $AgNO_3$ solution. What type of bond do you expect in the compound and why ?

Teacher's Guide

Understanding of chemical bond formation between two atoms is very important for a chemistry course. It is only within the past fifty years that scientists have really begun to understand the nature of chemical bond.

As octet formation is one of the general requirement for the formation of both electrovalent and covalent bonds, the octet rule may be discussed in the class. The formation of a chemical bond between any two atoms (A and B) may be discussed in reference to changes in energy and completion of octet of outermost shell of both the atoms A and B The formation of electrovalent and covalent bonds may be discussed with examples of simple molcules. The students may be asked to write the electron-dot formulae of various substances. As the students have done electronic configuration of only the first twenty elements, the examples of bond formation should involve only first twenty elements.

The reason for the formation of a particular type of bond (electrovalent or covalent) between the two atoms may be discussed in terms of the capacity of an atom either to lose, gain or share the electrons with the other atom.

The students may be asked to construct the models of simple molecules using locally available materials such as iron wire and beads. The iron wire is used to make the energy shells and beads respiesent electrons.